University of BRISTOL

Evaluating the effect of antenna tilt and rotation on antenna performance in an indoor environment

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Aim of study

Undertake an initial evaluation of the performance of antenna elements suitable for a mobile handset for operation at 5.2GHz

- See how performance varies with tilt and rotation of antennas
- Require suitable measured angle of arrival (AoA) data
- Need to benchmark performance

Plan of action

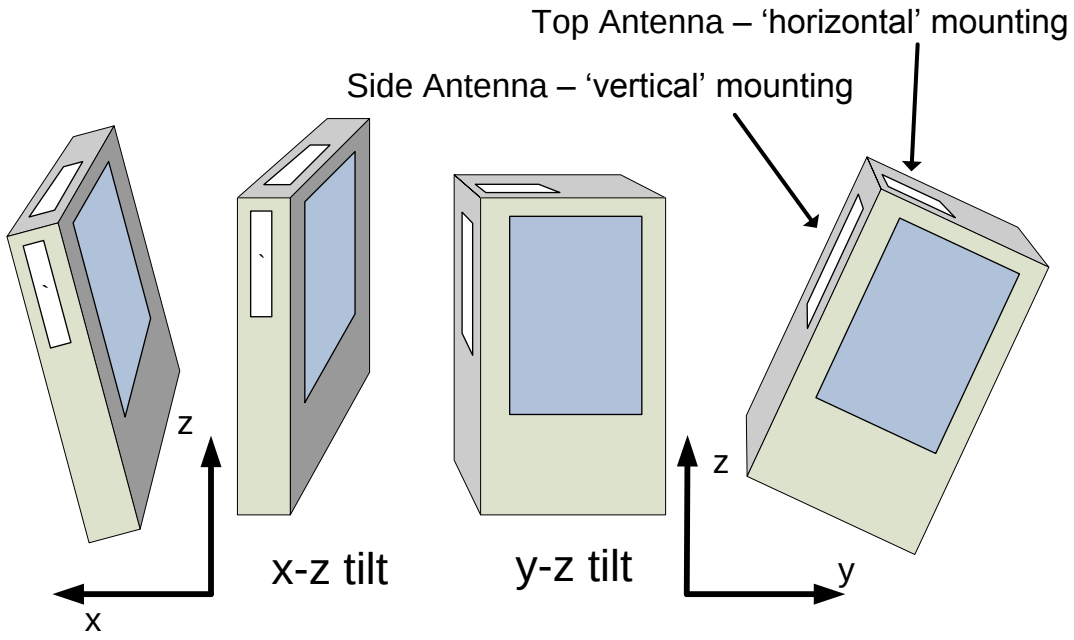
Antenna elements: 3 element types (Cavity-backed Slot, Printed Inverted-F and Dielectric Resonator) at two positions on a small mobile terminal

Propagation data: Combine the measured full (3D) far-field radiation patterns of each antenna with measured AoA data for a laboratory/office space

Terminal orientation: Tilted and rotated in order to determine the variation in performance that is obtained for the 3 transmitter locations

Benchmarking: Results are presented as cumulative distribution functions of directivity relative to a benchmark Hertzian dipole for operation at 5.2GHz

Antenna orientation

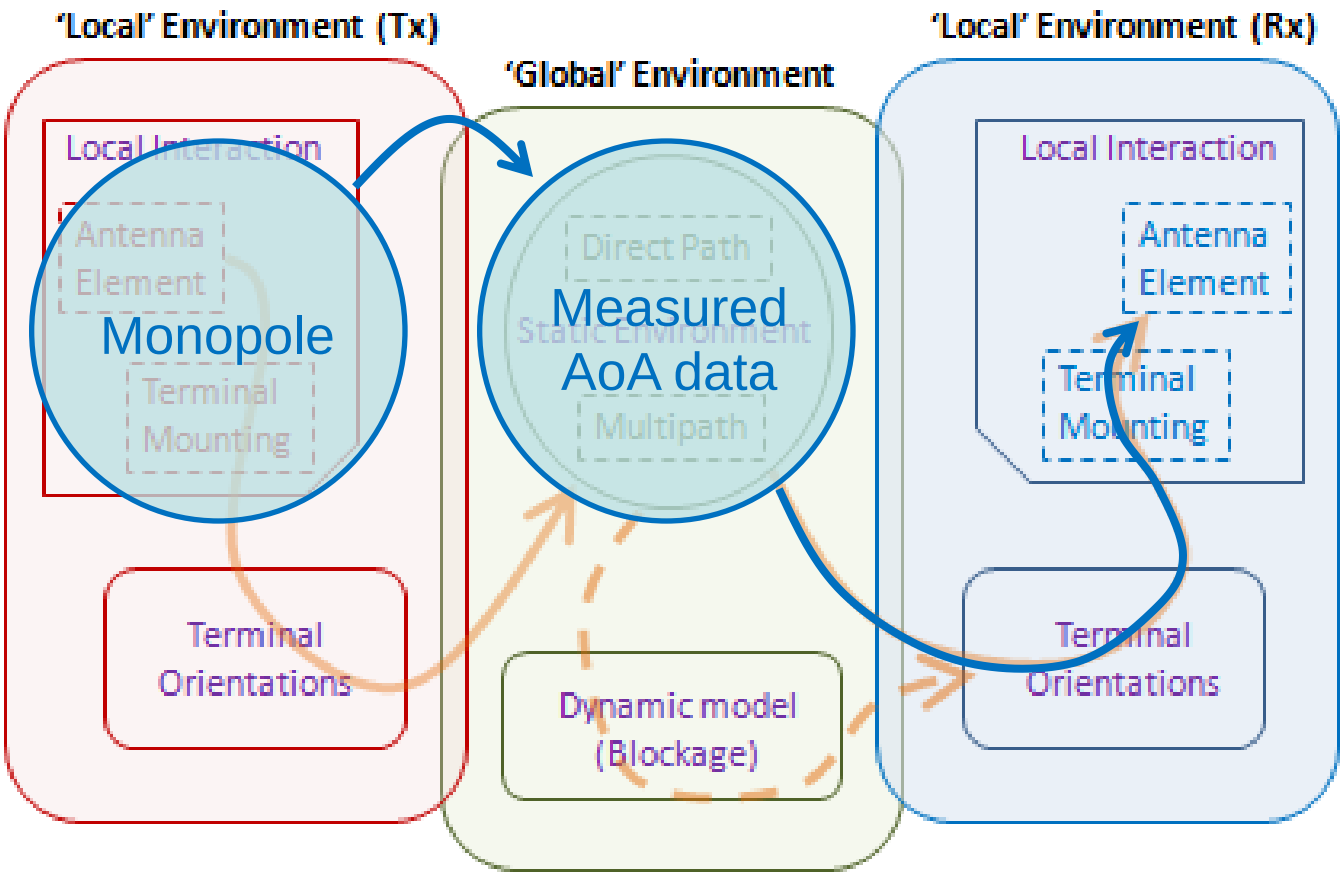


Antenna tilted in y-z plane:
Range 5^{o} to 45^{o}

Antenna tilted in x-z plane:
Range 0^{o} to 60^{o}

Two antenna mounting positions on terminal:
11cm high, 6cm wide,1.4cm thick

The bigger picture

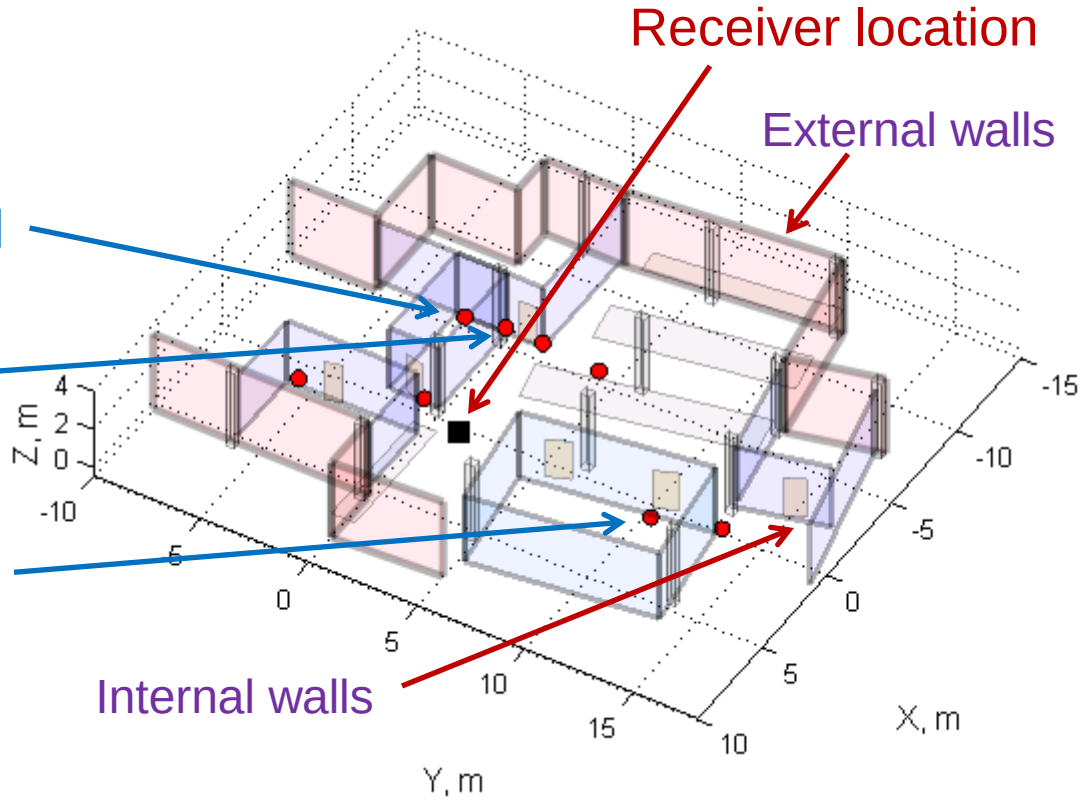


For full antenna evaluation need to take into account all of this

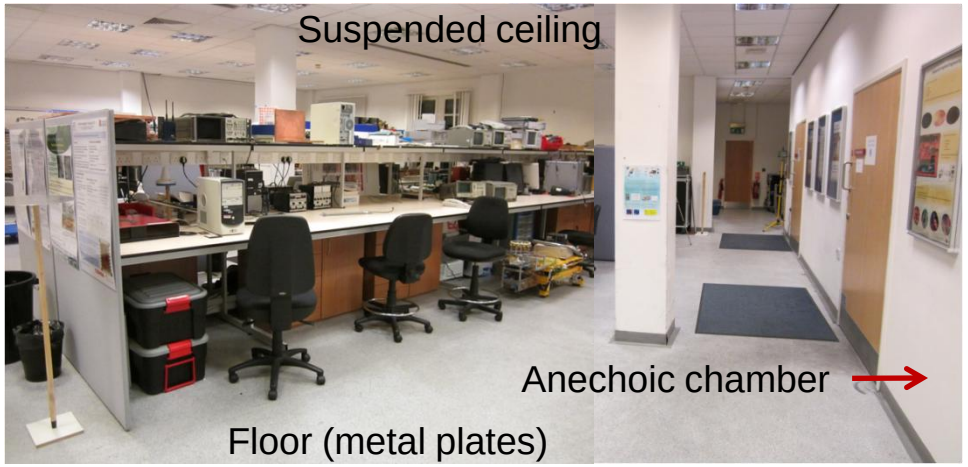
Transmitter positions

Measurements performed at 10 transmitter locations in Laboratory

- Consider 3 of the transmitter positions here
- Single floor level



Laboratory environment



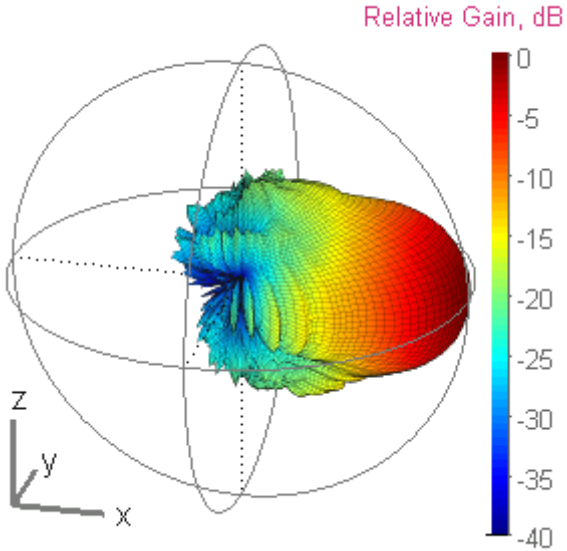
Open plan environment:

- Floor area about 18m by 20m
- Ceiling height >3.2m

- High and low level benching

Scanning antenna

Antenna used to scan full Azimuth & Elevation for both V & H-polarisations

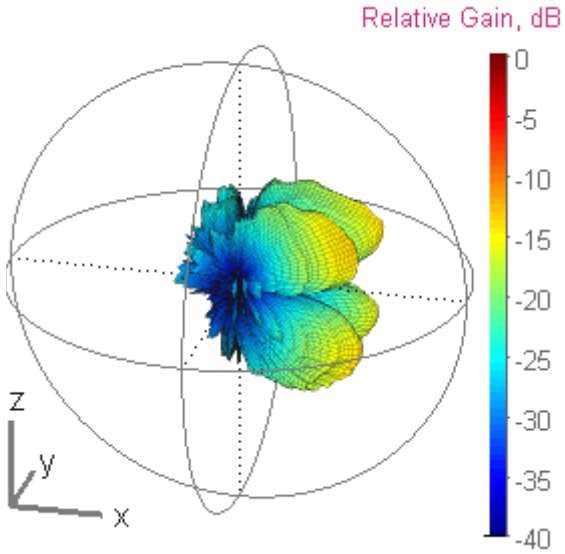


Co-polar response

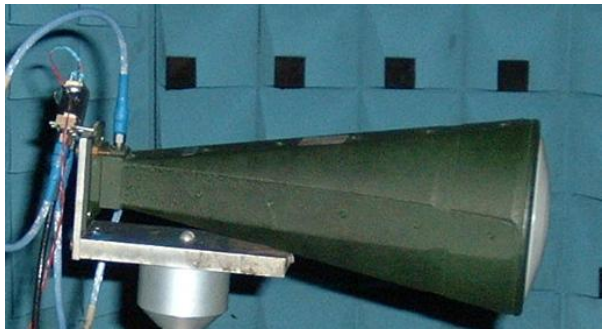
Measured far-field radiation patterns (vertical feed)

Flann dual-polarised horn antenna

- Directivity of 14.5dBi at 5.2GHz
- 30º & 33º HPBWs in principal planes

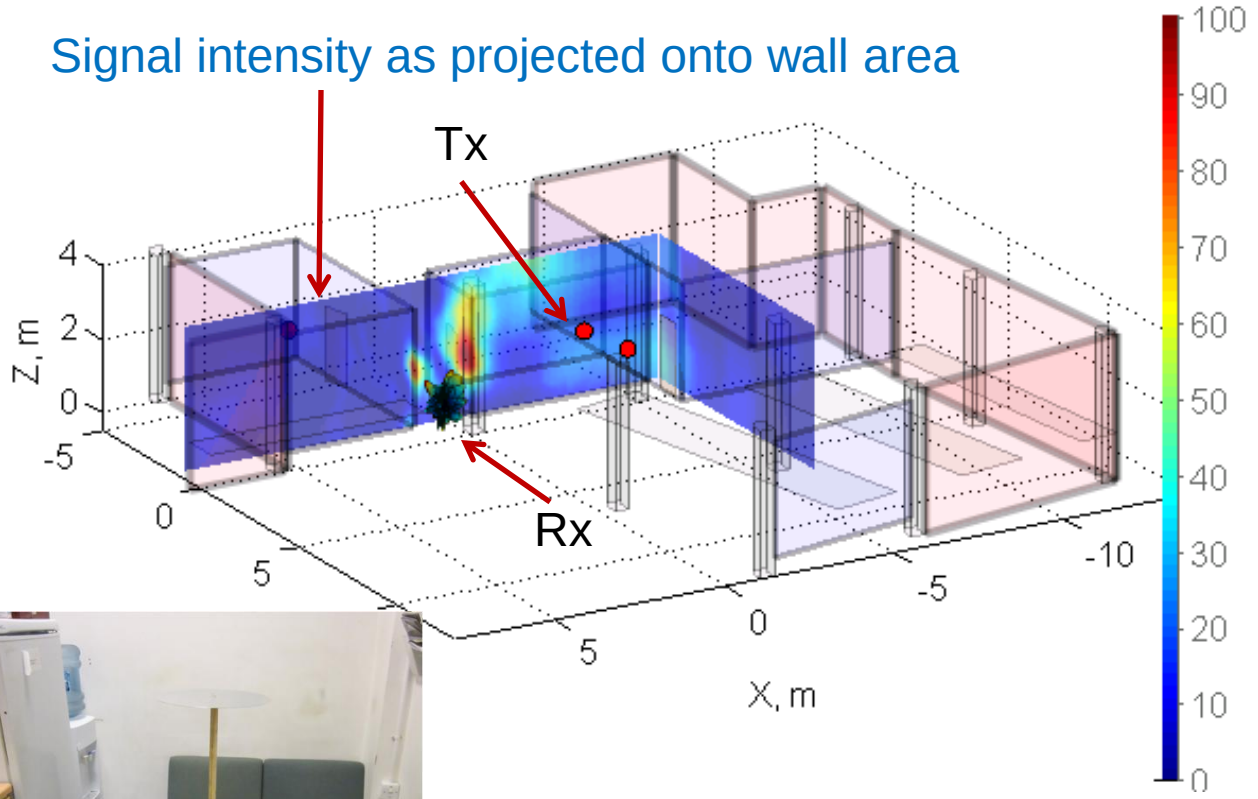


Cross-polar response

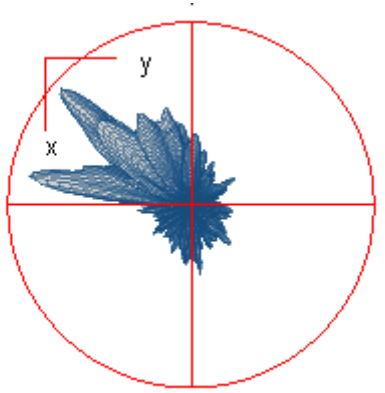


Transmitter in kitchen

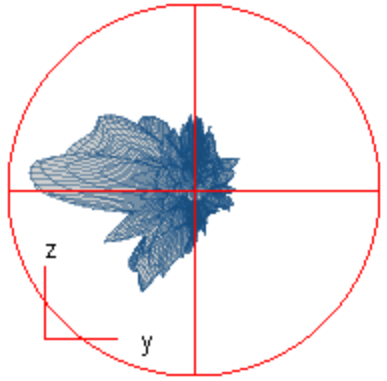
Signal intensity as projected onto wall area



Measured data from scanning antenna

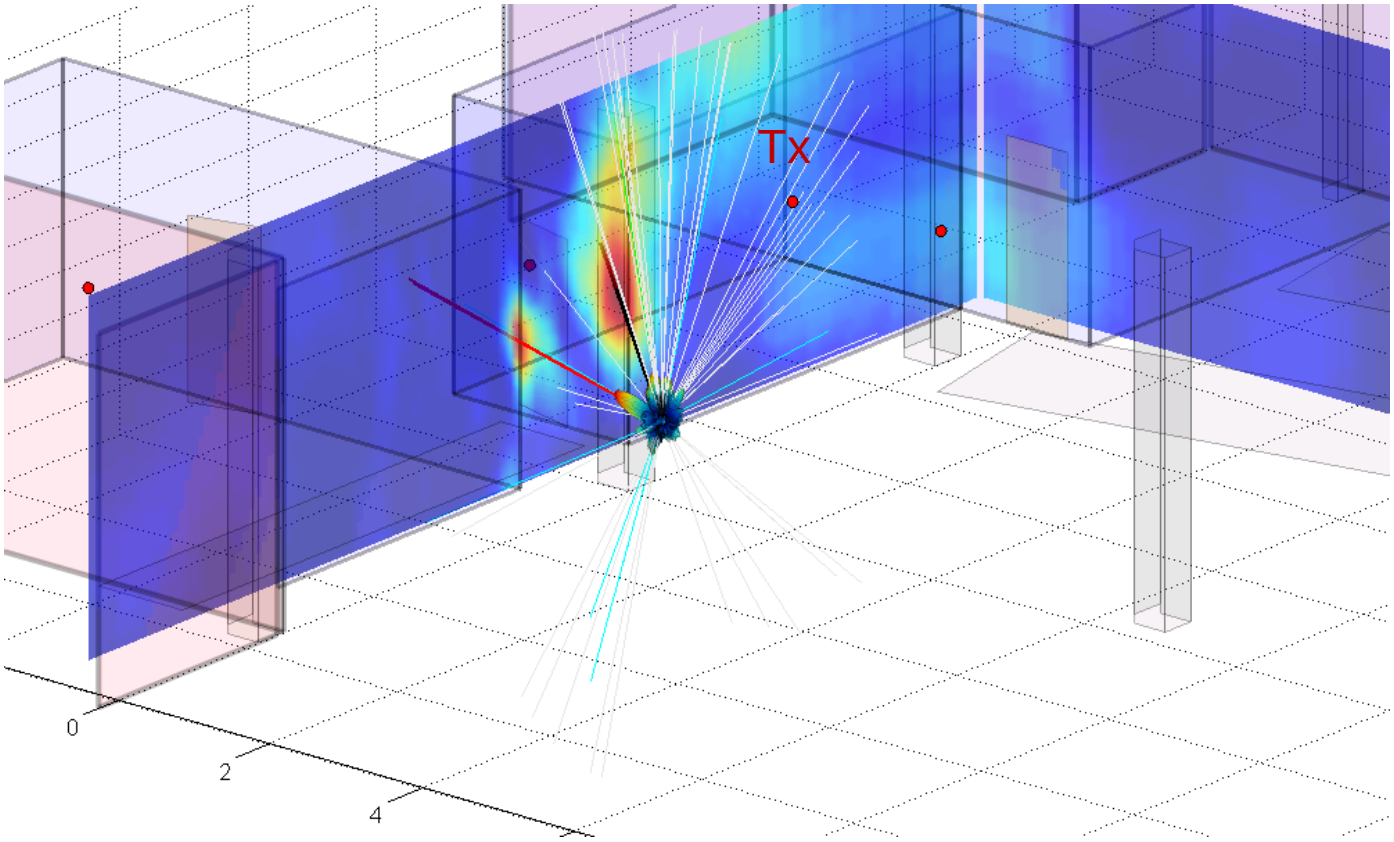


Azimuth



Elevation

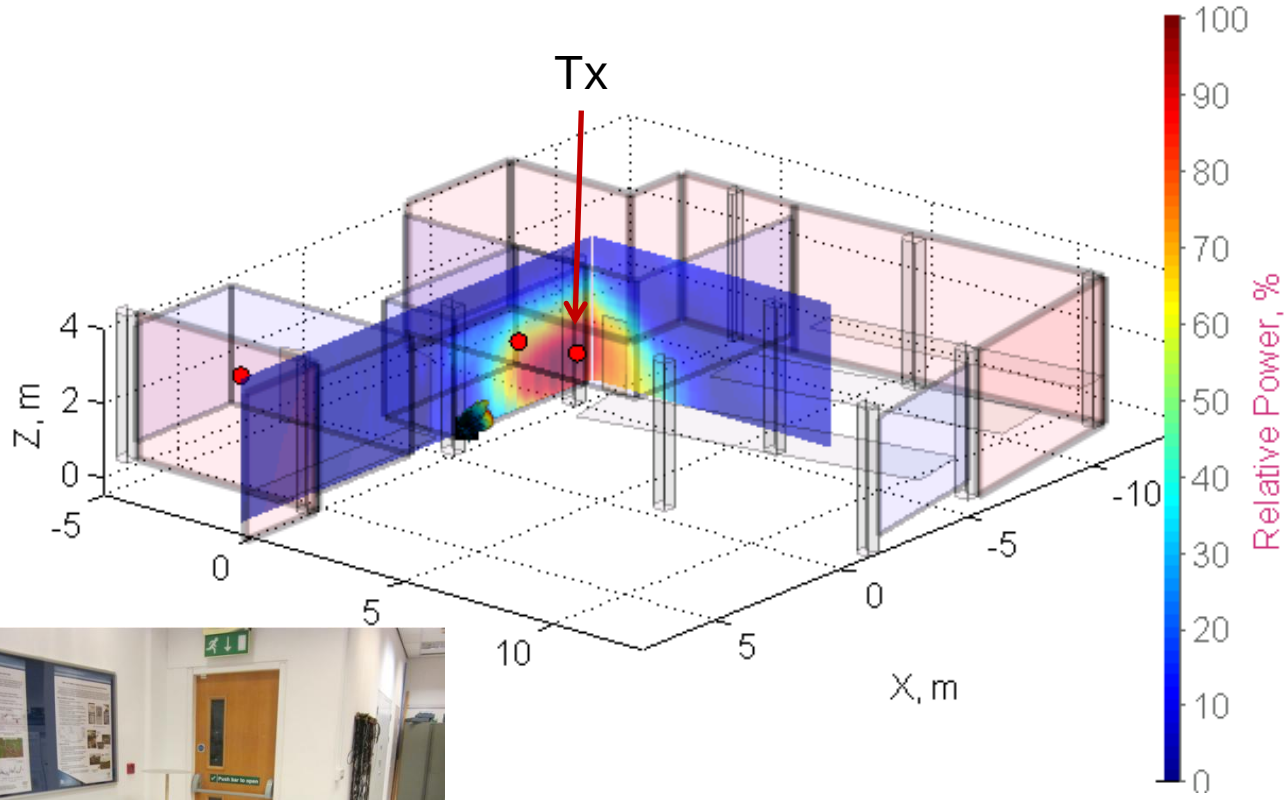
Signal AoAs

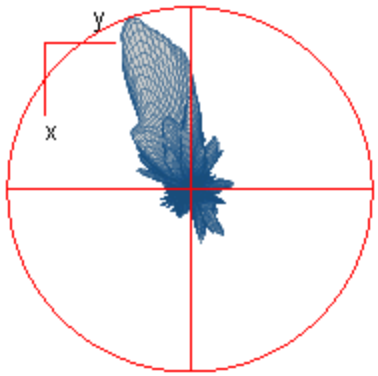


Process raw data to determine AoA components (Tx in Kitchen)

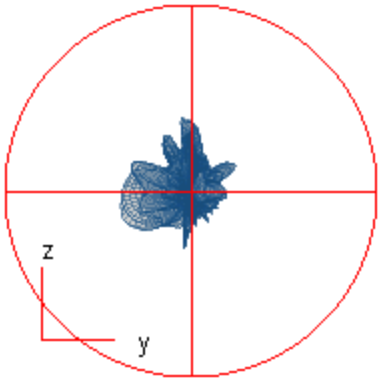
Process is being refined to improve the AoA determination

Corner of laboratory





Azimuth



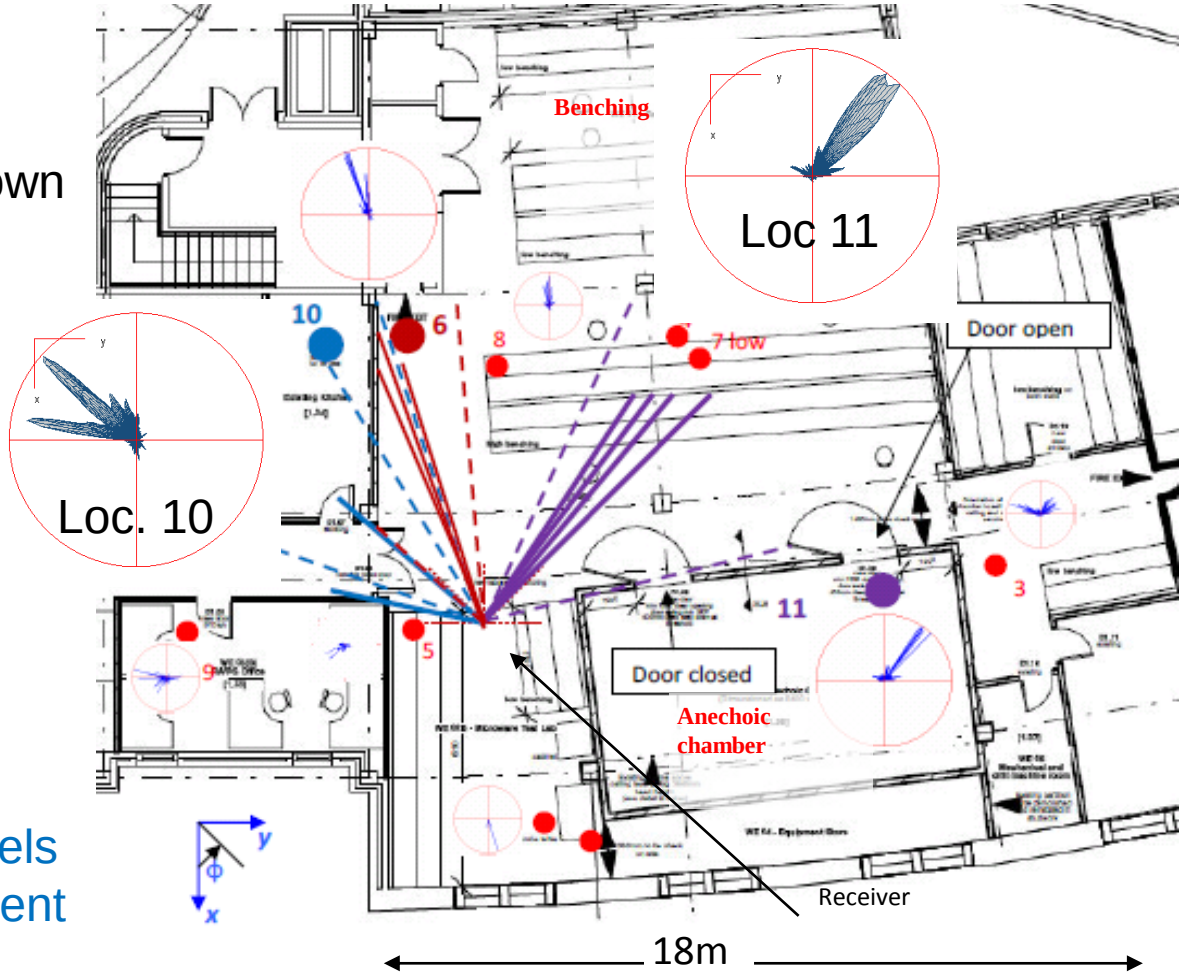
Elevation

Corner of room resembles
a corner reflector antenna

Main ray paths

The main ray clusters are shown for each of the 3 locations

- azimuth perspective

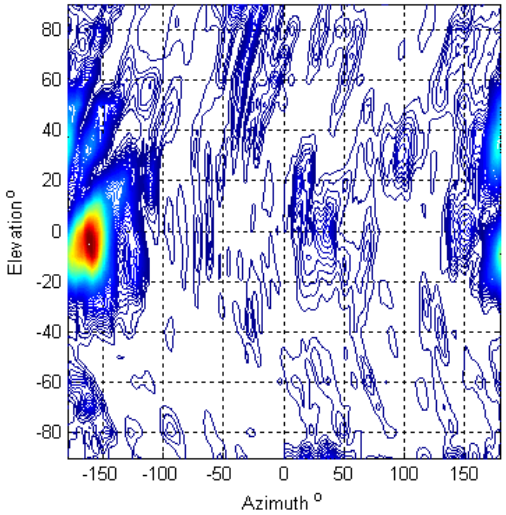


Colour indicates Tx position:

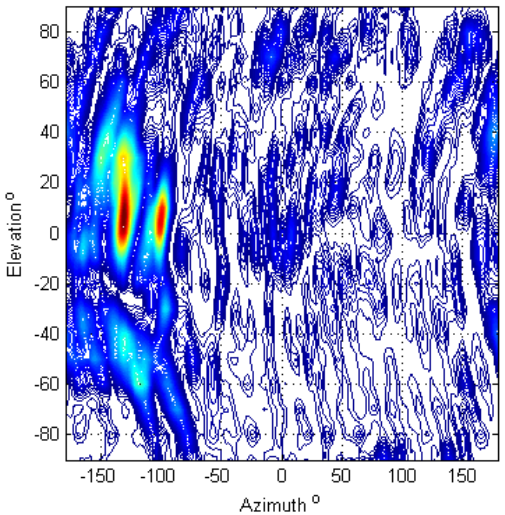
- Solid lines show highest levels
- Dotted lines indicate the extent of high level signals

Summary of signal strengths

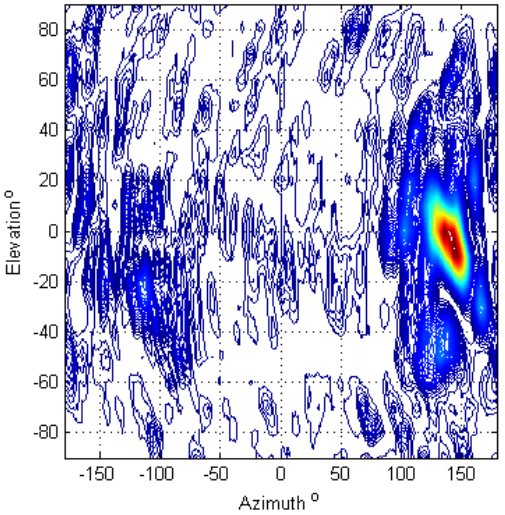
Corner of Lab (LoS)



Kitchen



Chamber



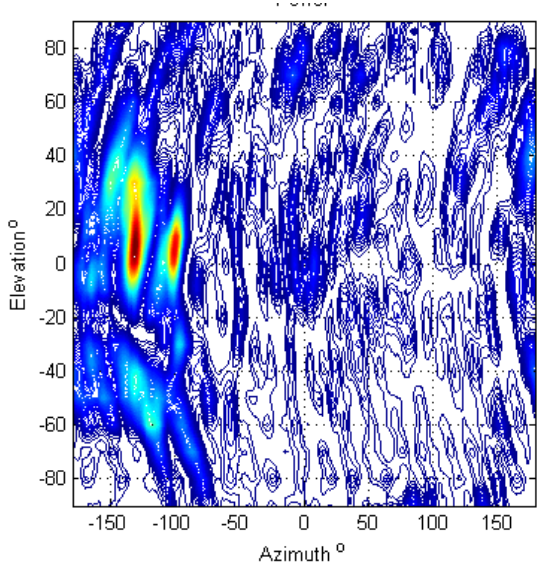
Full azimuth & elevation perspective

- Relative power levels, Tx (V) – Rx (V)
- Blue indicates signal levels of 10dB below peak levels

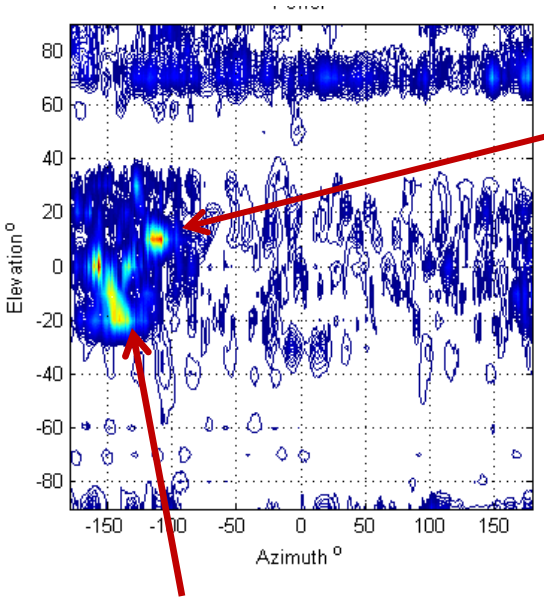
•Tx (V) - Rx (H) levels are 8.3dB lower for LoS and 3.5dB for Chamber

Measurement repeatability

Kitchen
(raw data)



Difference
(data normalised to maximum)

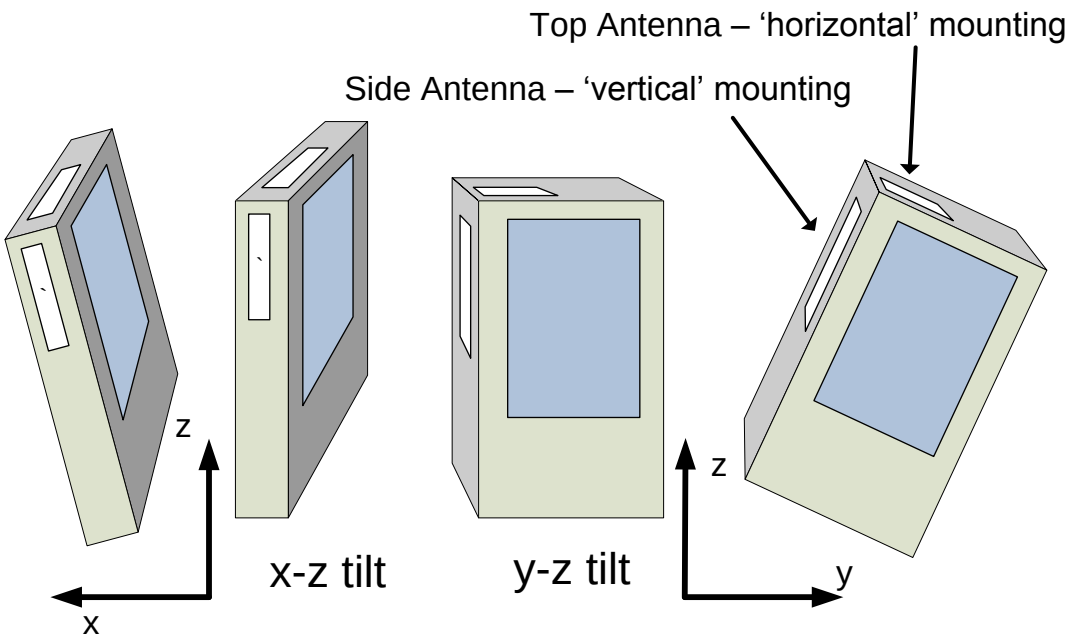


Along corridor

Entrance to kitchen

Peak value for difference pattern is 7dB lower than raw data

Antenna orientation - reminder



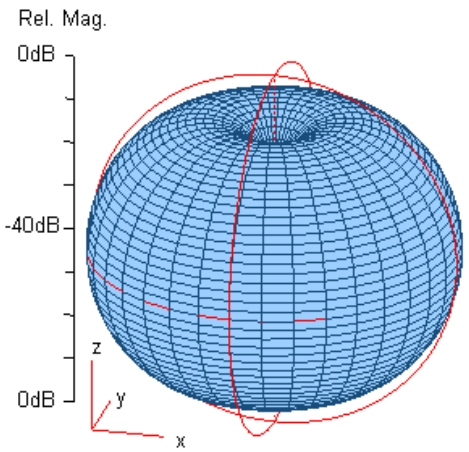
Antenna tilted in y-z plane:
Range 5º to 45º

Antenna tilted in x-z plane:
Range 0º to 60º

Antenna rotated in x-y plane:
Range 0º to 360º

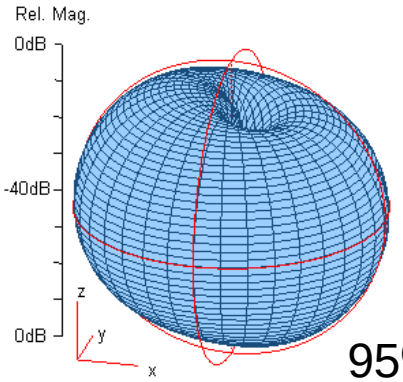
Apply equal probability for all configurations

Example of antenna tilt



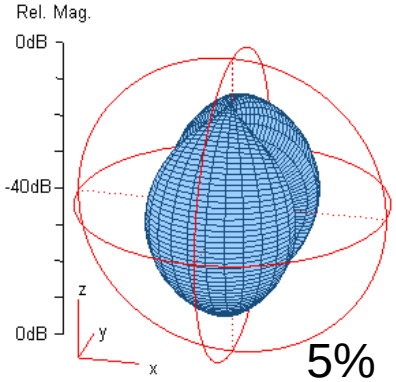
Ideal Dipole
- z-directed
- no tilt
- vertical polarisation

15° tilt



95%

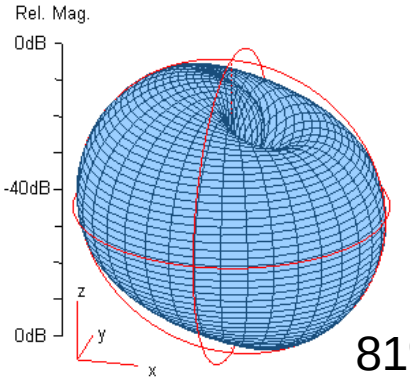
Vertical components



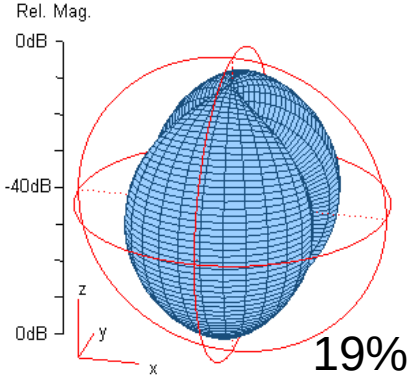
5%

Horizontal components

30° tilt



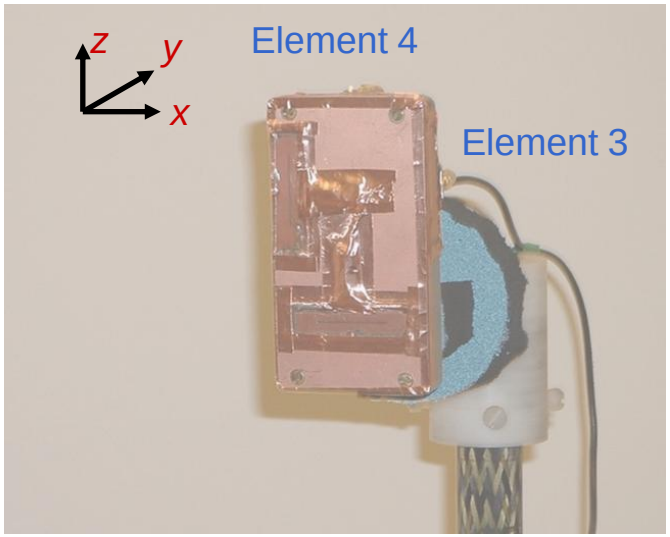
81%

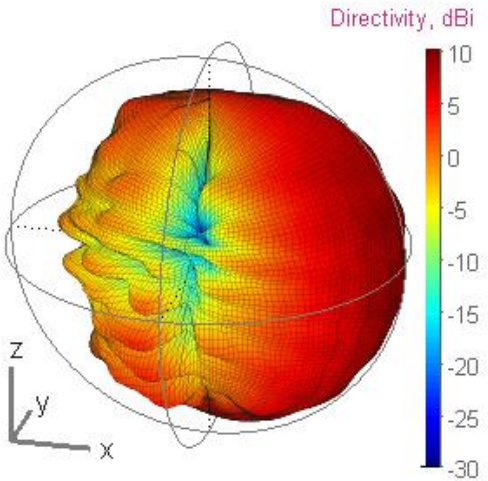


19%

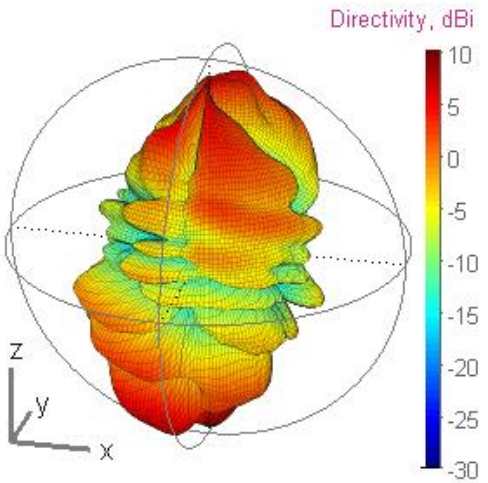
Also need to rotate around z-axis

Cavity-backed slot antenna





Vertical component

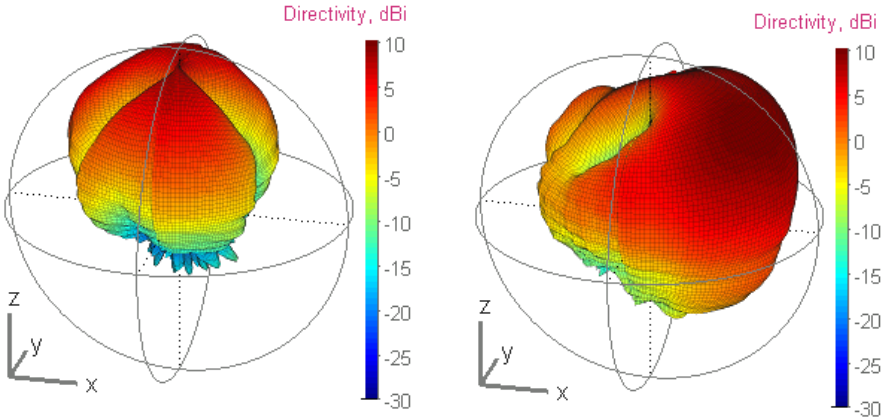


Horizontal component

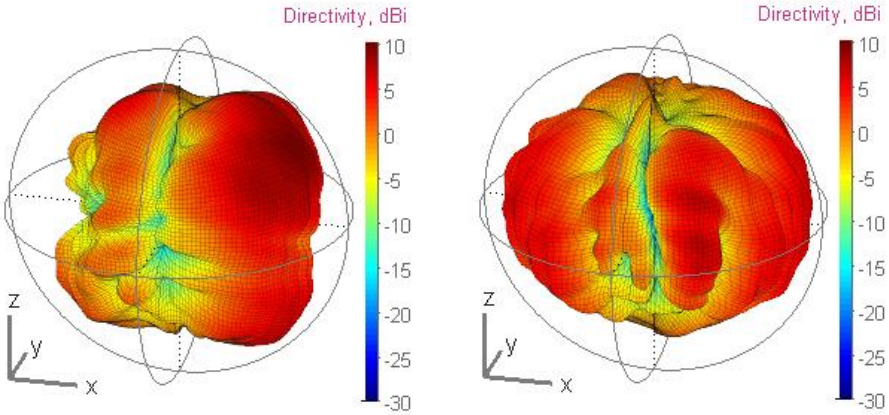
Measured far-field radiation patterns for Element 3 (side)

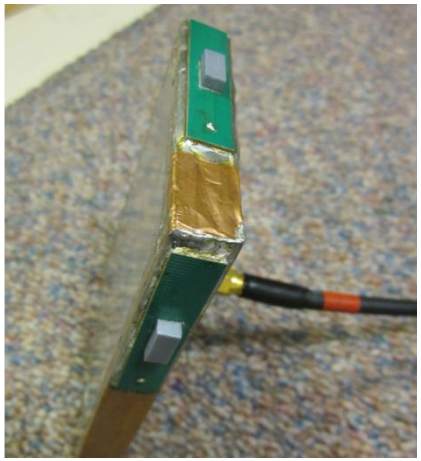
A. Pal, C. Williams, G. Hilton, and M. Beach, “Evaluation of Diversity Antenna Designs Using Ray Tracing, Measured Radiation Patterns, and MIMO Channel Measurements”, *EURASIP Journal on Wireless Communications and Networking*, Article ID 58769, 2007.

DRAs & IFAs



Vertical components Horizontal components

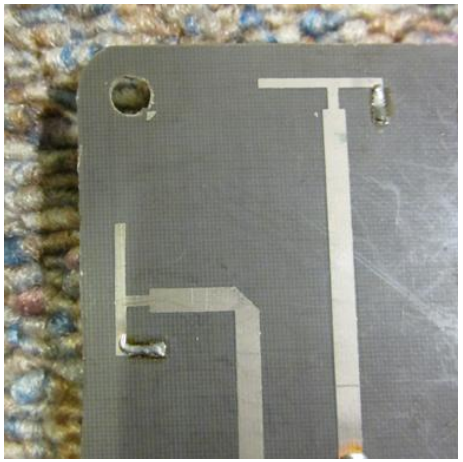




Patterns for one of each type of element

Dielectric resonator

Inverted F



York University and Antenova designs

Directivity levels

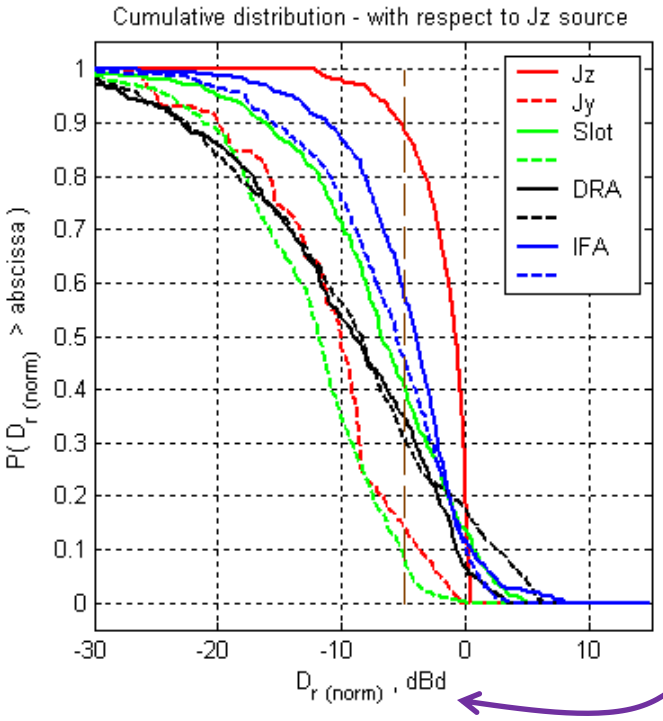
Slot		DRA		IFA		Ideal dipoles	
Top	Side	Top	Side	Top	Side	Jz	Jy
6.8	6.5	7.8	7.2	8.8	5.9	1.8	1.8

Maximum Directivity levels for the elements in dBi

All practical elements on terminal have a Directivity between 5.9 and 8.8dBi

IFA has variation of about 3dB with same element though different position on terminal

Statistical analysis



Cumulative Distribution showing outcome of antenna tilts in two planes with full 360º rotation

Antenna field levels

AoA field levels

Polarisation misalignment

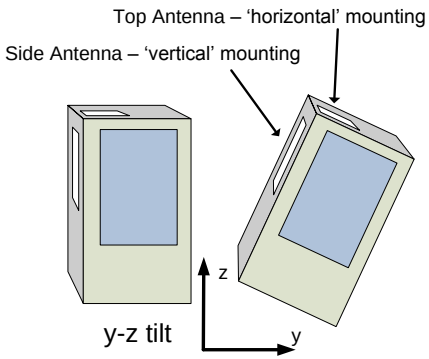
No. of paths

Normalisation: Jz source, no tilt

$$D_{r(norm)} = 10\log\left|\frac{\sum_{n=1}^{N} g_n C_n \Gamma_n}{\sum_{n=1}^{N} d_n C_n \Gamma_n}\right|^2$$

Solid line – top antenna
Dashed line – side antenna

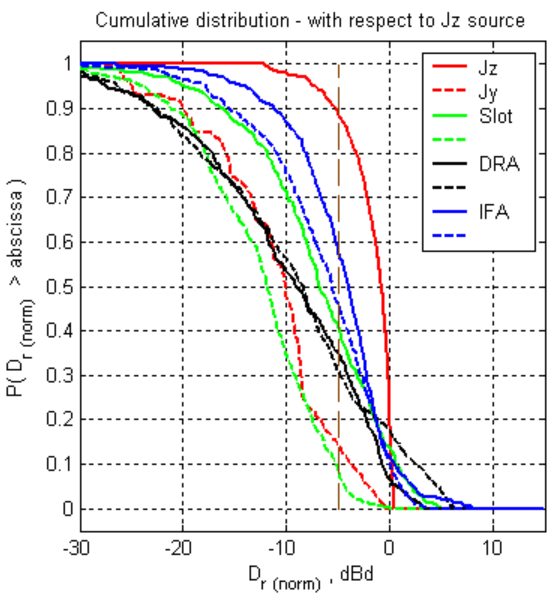
$$|g_n|^2 = D(\theta_n, \phi_n)$$



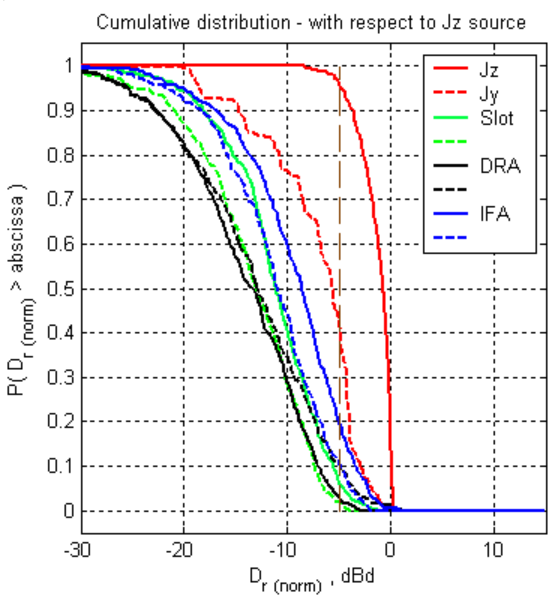
Vertical and horizontal orientations for all types of element

Summary of results

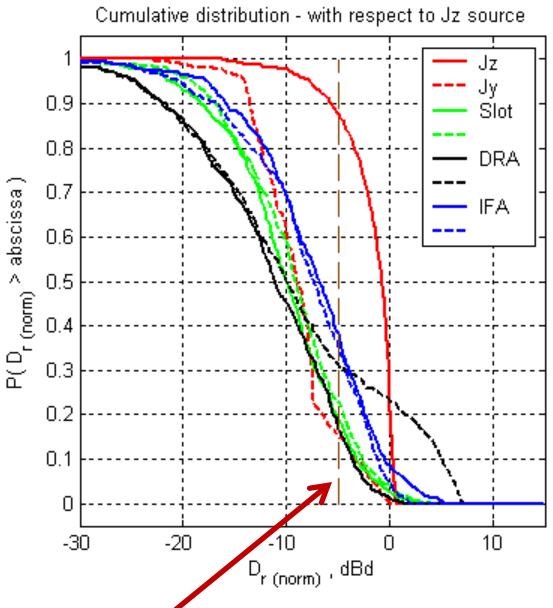
Corner of Lab.



Kitchen



Chamber



How to analyse overall performance?

- Plots mainly to right – better overall performance
- Levels below a given threshold, say -5dBi (‘outage’)

Azimuth rotation tends to favour the more omni-directional elements
Vertical Tx favours antennas with more dominant vertical component

Conclusions

AoA data for a number of transmitter locations within an indoor environment are considered, and these show that with no direct (visible) LoS, the signals reaching the receiver tend to be dominated firstly by the diffracted paths and then any reflected paths - these tend to be clustered

For the environment considered, it is a predominantly ‘static’ environment and hence magnitudes & phases of received signals are similar with repeat measurements

Variations in element patterns result in directivities ranging from 5.9 to 8.8dBi, though this does not help to identify which element will perform best under the test conditions considered here.

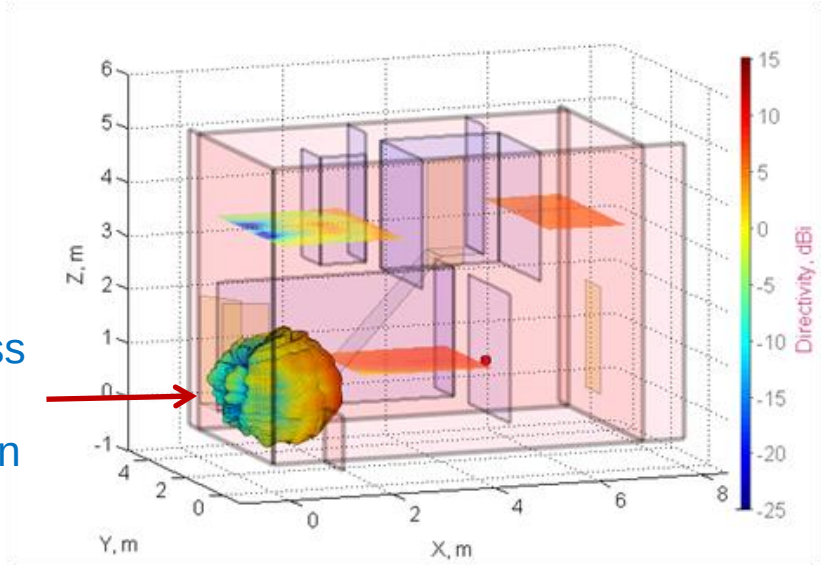
Variations in signal strength of greater than 30dB (with respect to the benchmark dipole) were observed due to polarisation misalignment and pattern directivity.

Where to next?

- Programme of measurements for home & office environments

- Use of access point antennas in addition to monopole Tx
- Use of horizontal and vertical polarisations for Tx

Access point pattern



Evaluating system performance on different floors in a terrace house

Any Questions?